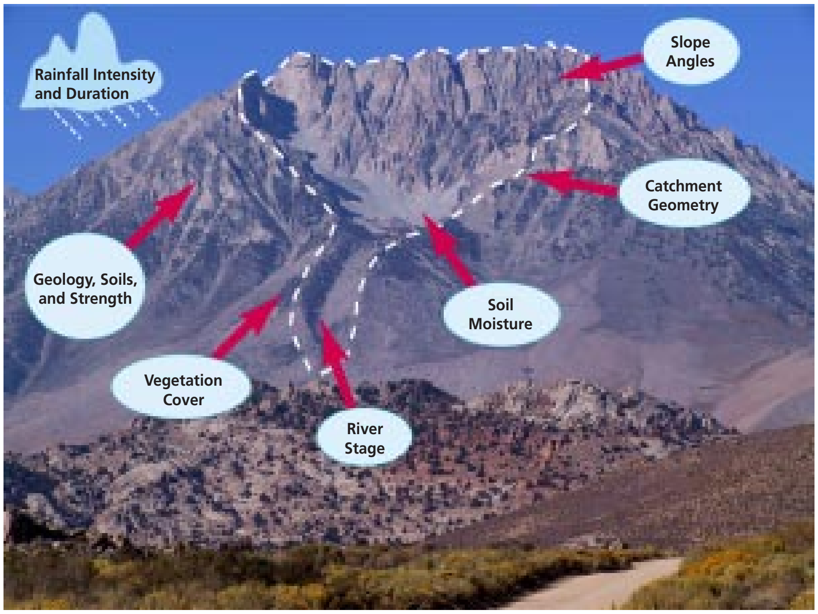
How is the Land Surface Changing and Producing Natural Hazards?

Expected Accomplishments

- *Development of a process-based understanding of the tectonic–climatic–biotic interactions that create landscapes*
- *Quantification of natural baselines and rates of change of the land surface*
- *Quantification of the causes, magnitude, and development in time and space of natural hazards*
- *Assessment of the relative roles of natural and human-induced changes*

Benefits for the Nation

- *Real-time prediction of the progression of floods, landslides, and coastal erosion*
- *Assessment of susceptibility to damage by natural hazards*
- *Quantification of watershed dynamics, hydrology, and landscape response*
- *Definition of the human role in influencing the landscape and abating and aggravating hazards*



Prediction of hazardous processes such as floods or landslides requires quantification of both changing landscape characteristics and climatic inputs.

The Challenge

In order to lessen the impact of natural hazards, we need to characterize, understand, and predict the phenomena that cause them. The land surface is the dynamic interface between the lithosphere, hydrosphere, and biosphere. It is where interactions represent the most direct and commonly occurring impacts of solid-Earth science on humans. Landslides, floods, tsunamis, debris flows, storm surges, earthquakes, and volcanic eruptions sculpt and deform the land. The Earth's surface constitutes the geomorphic record of past tectonic–climatic interactions and is the topographic template upon which new natural hazards are generated. The challenge presented by the land surface is three-fold: to unravel the record of past interactions embedded in this surface, to determine the relative roles of natural and human-induced change, and to understand processes that act on this surface in order to predict and mitigate natural hazards. Reconstruction of past erosion, deformation, and deposition and quantification of tectonic, climatic, and biologic inputs to the evolving landscape will underpin the ability to develop a process-based understanding of the Earth's dynamic surface.

What We Know and Need to Learn about Land Surface Change and Natural Hazards

We know the land surface evolves as tectonic forces cause deformation and as transient hydrologic and biologic forces mediate erosion and deposition on the surface. The majority of the destructive

U.S. earthquakes of the last twenty years occurred on faults that did not rupture the surface, although they deformed the land surface above the fault and promoted new patterns of erosion. Interpretation of the deformed land surface allows us to construct rates of fault growth and past seismic activity. As large storms rain upon the land, topography, soils, vegetation, and rainfall intensity determine how floods and landslides are generated. We know that the amount of antecedent rainfall, soil cohesion and water content, recent fire history, water routing through the landscape, and hillslope angles all interact to determine where and when a landslide will occur. Similar interactions determine how flood waves will migrate through a catchment and how much sediment will be eroded, transported, and deposited during a storm.

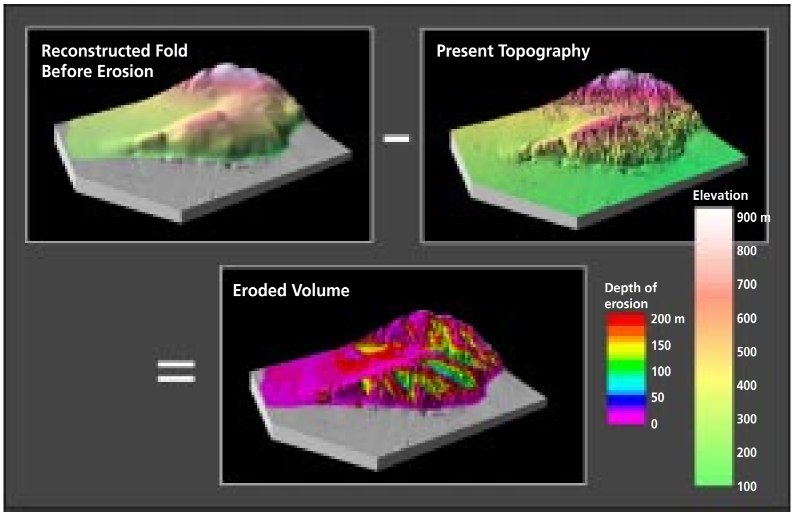
Next Steps

Remotely sensed data play an integral role in reconstructing the recent history of the land surface and in predicting hazards due to events such as floods and landslides. Because land-surface properties change through time, remote sensing of such changes yields critical time control on landscape evolution. Remotely sensed data can determine properties of the surface and atmosphere in real time and with a high spatial resolution. Recognition that destructive floods or landslides can be launched by intense, short-lived storm cells a few kilometers in width pinpoints the need for higher spatial and temporal resolution of remotely sensed data. At present, even "well monitored" river catchments commonly have only a few gauges measuring precipitation and discharge. Few data exist on soil moisture, thickness, and strength, or on vegetation cover, fire history, or detailed topography. The only practical way to gather these data is through implementation of a broad-based remote-sensing program. The height and width of rivers, as well as rainfall intensity and amounts, need to be measured hourly during storms. Developing a process-based understanding of natural hazards depends on studies of the character of previous and ongoing events.

Information needed to address the challenges falls into the categories of surface, subsurface, and hydrologic characterization. These categories have diverse observational requirements. Those that change rapidly, such as river stage or precipitation, call for hourly measurements, whereas others, such as vegetation, commonly require seasonal measurements. Occasional (5–10 yr) quantification of soil composition and thickness would suffice in areas governed by gradual processes, but more frequent measurements will be needed in areas affected by such dynamic events as flooding or landsliding. The remote sensors that will provide these data include InSAR, GPS, visible and near infrared/thermal infrared (VNIR/TIR) imaging, multi-parameter SAR, laser altimetry, and microwave imaging. These observations will need to be augmented with extensive land-based measurements and data from existing and new hydrologic, seismologic, and geodetic arrays. By means of frequent, high-resolution remote sensing, a new capability will emerge for predicting hazards caused by tectonic–climate–land surface interactions.

"A man should examine for himself the great piles of superimposed strata, and watch the rivulets bringing down mud, and the waves wearing away the sea-cliffs, in order to comprehend something about the duration of past time, the monuments of which we see all around us."

Charles Darwin, from the Origin of Species



Wheeler Ridge in Southern California is an example of a rapidly growing fold above a blind thrust. High-resolution topography defines uplift rates, erosion, and the interactions that produce natural hazards.